COMMERCIAL SPACE SYSTEMS USER PERSPECTIVE

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OUTLINE

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  - Commercial Telecommunications Space Systems.
  - Environment Models.
  - System Reliability and Availability.
  - Fault Tolerant Systems Engineering.
  - Validation and Verification of System Performance / Availability.
  - Importance of Testbeds in Validating Development Methodology.
  - Space Weather Support of Constellation Operations.
  - Conclusions.

MOTOROLA
Systems Solutions Group

COMMERCIAL SPACE SYSTEMS

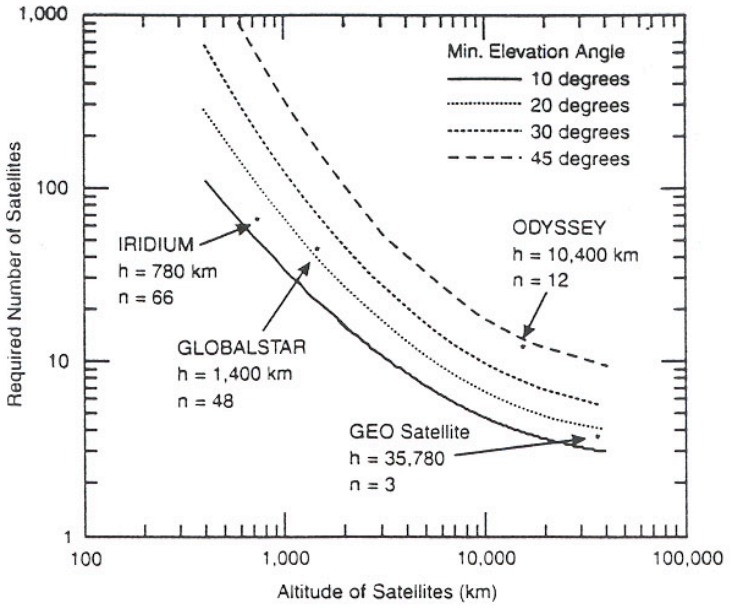
	Orbit Architecture			
	GEO		MEO	LEO
	Regional	Global		
Narrowband Systems	ACeS (Asia) APMT (Asia) ASC/Agrani (Mid-East) EAST (Europe) Satphone (Africa) Thuraya		ICO	ECCO/Constellation Ellipso Globalstar Iridium GMPCS Systems
Broadband Systems (BSS)		Astrolink CyberStar Expressway Spaceway	Spaceway	SkyBridge Teledesic

New Satellite Telecommunications Systems

Broadband Satellite Systems

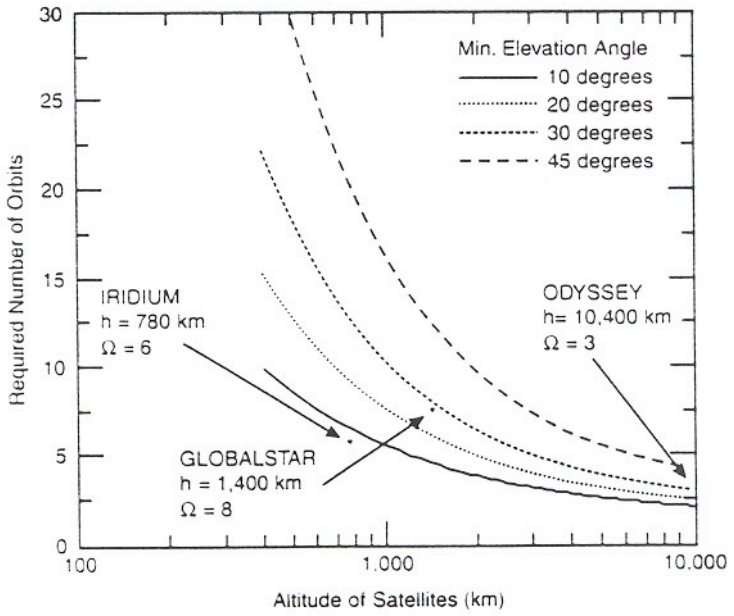
	Satellite System	Communications Band	Lead Participants	Number of Satellites
Broadband GEO	Astrolink	Ka	Lockheed Martin	5 - 9
	CyberStar	Ka	Loral, Alcatel	3
	Expressway	Ku/V	Hughes	14
	Spaceway	Ka	Hughes	8
Broadband MEO	Spaceway	Ka	Hughes	20
Broadband LEO	SkyBridge	Ku	Alcatel, Loral	80
	Teledesic	Ka	Motorola, Boeing, Gates, McCaw	288

COMMERCIAL SPACE SYSTEMS

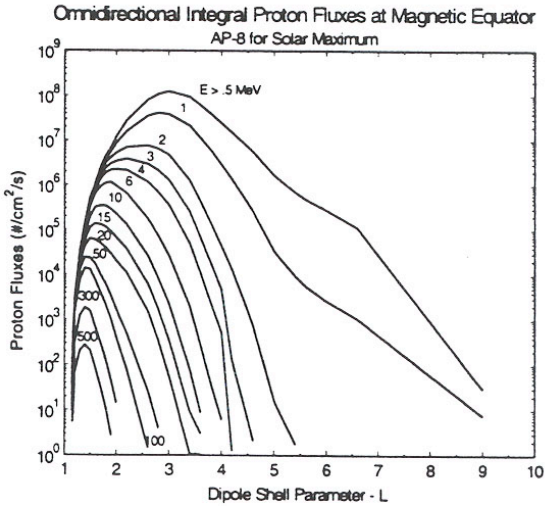


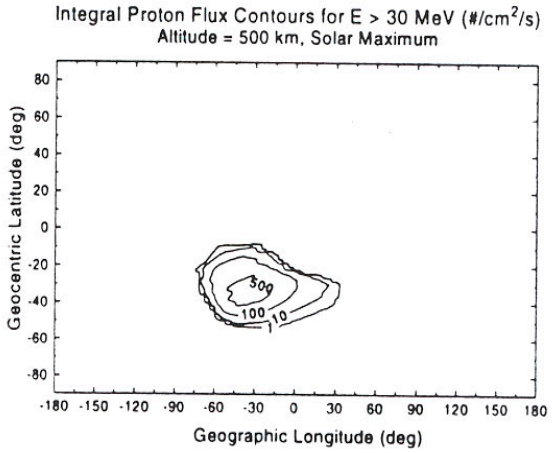
Number of Satellites for Global Coverage

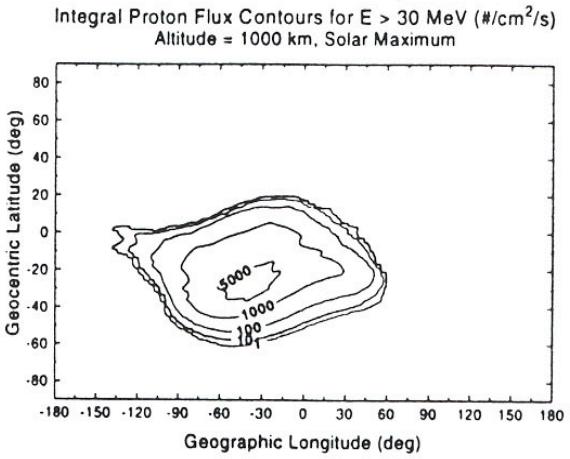
Number of Orbit Planes for Equatorial Coverage

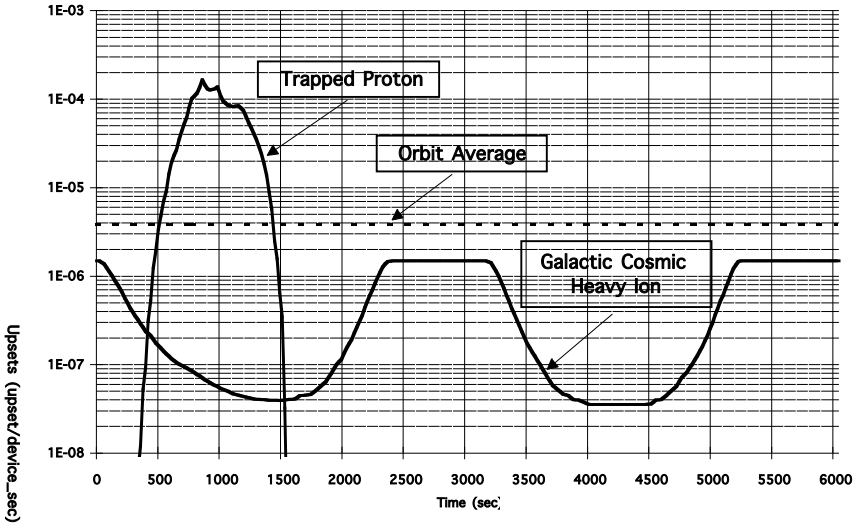


ENVIRONMENT MODELS









RELIABILITY AND AVAILABILITY

- SYSTEM RELIABILITY AND AVAILABILITY
  - Trends in Devices and Technologies Considered as Candidates for Satellite Applications.
    - Scaling is Producing Increased Total Ionizing Dose Tolerance.
    - Increased Availability of Thin-Epi in Manufacturers and Foundries.
      - Increased Availability of Single Event Latchup (SEL) Solutions.
    - Scaling Results in Increased Susceptibility to Single Event Upset (SEU).
      - Decreased Static Critical Charge.
      - Clock Frequencies Approaching Single Event Transient Lifetime.
  - Reliability.
    - $R(t) = e^{-\lambda t}$ $\lambda = 1 / MTBF$ *Mean Time Between Failure*
  - Availability.
    - $A = \mu /(\lambda + \mu)$ $\mu = 1 / MTTR$ *Mean Time To Detect and Recover*
      $\lambda = 1 / MTBF$ *Mean Time Between Faults*

FAULT TOLERANT SYSTEMS

- FAULT TOLERANT SYSTEMS ENGINEERING
  - Reduction in the Severity of the Environment.
    - Orbit Architecture.
    - Shielding.
  - Reduction in Charge Generation and Collection.
  - Elimination or Reduction in Circuit Response to Collected Charge.
  - Informational Redundancy.
    - Error Detection and Correction Coding.
  - Spatial and Temporal Redundancy.
  - Fault Detection.
  - Fault Containment.
  - System Recovery.

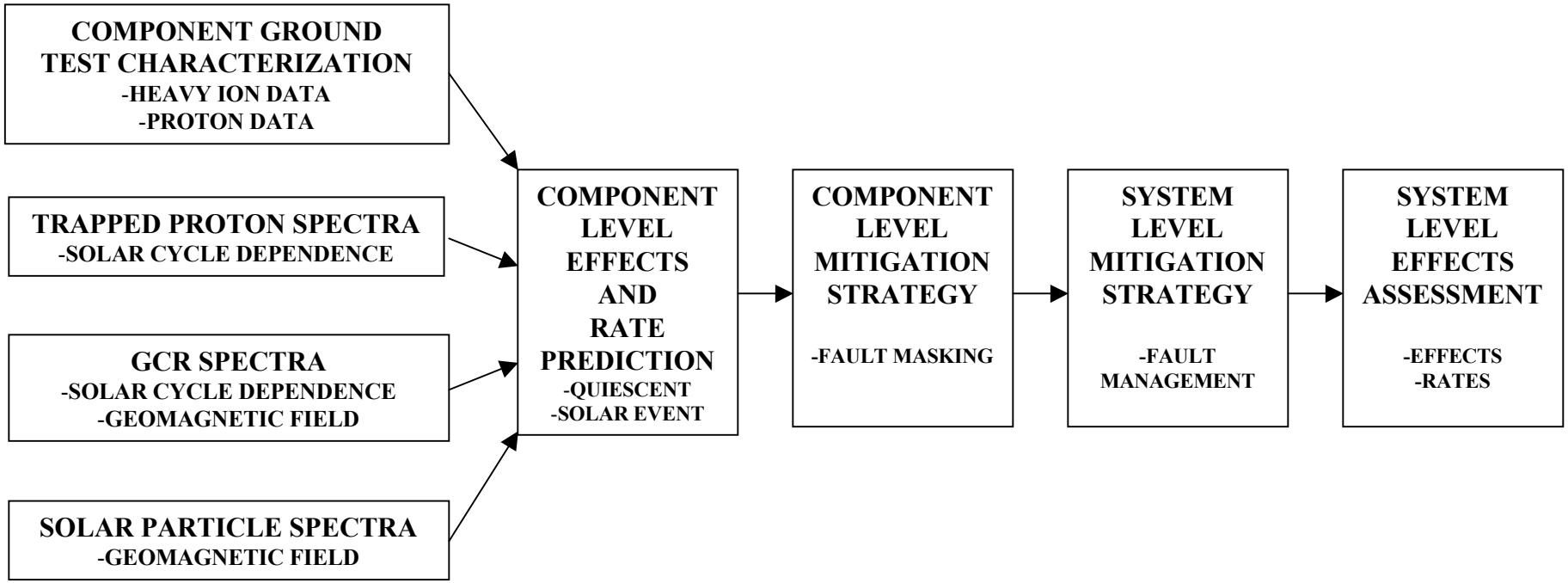
Fault Avoidance

Fault Masking

Fault Management

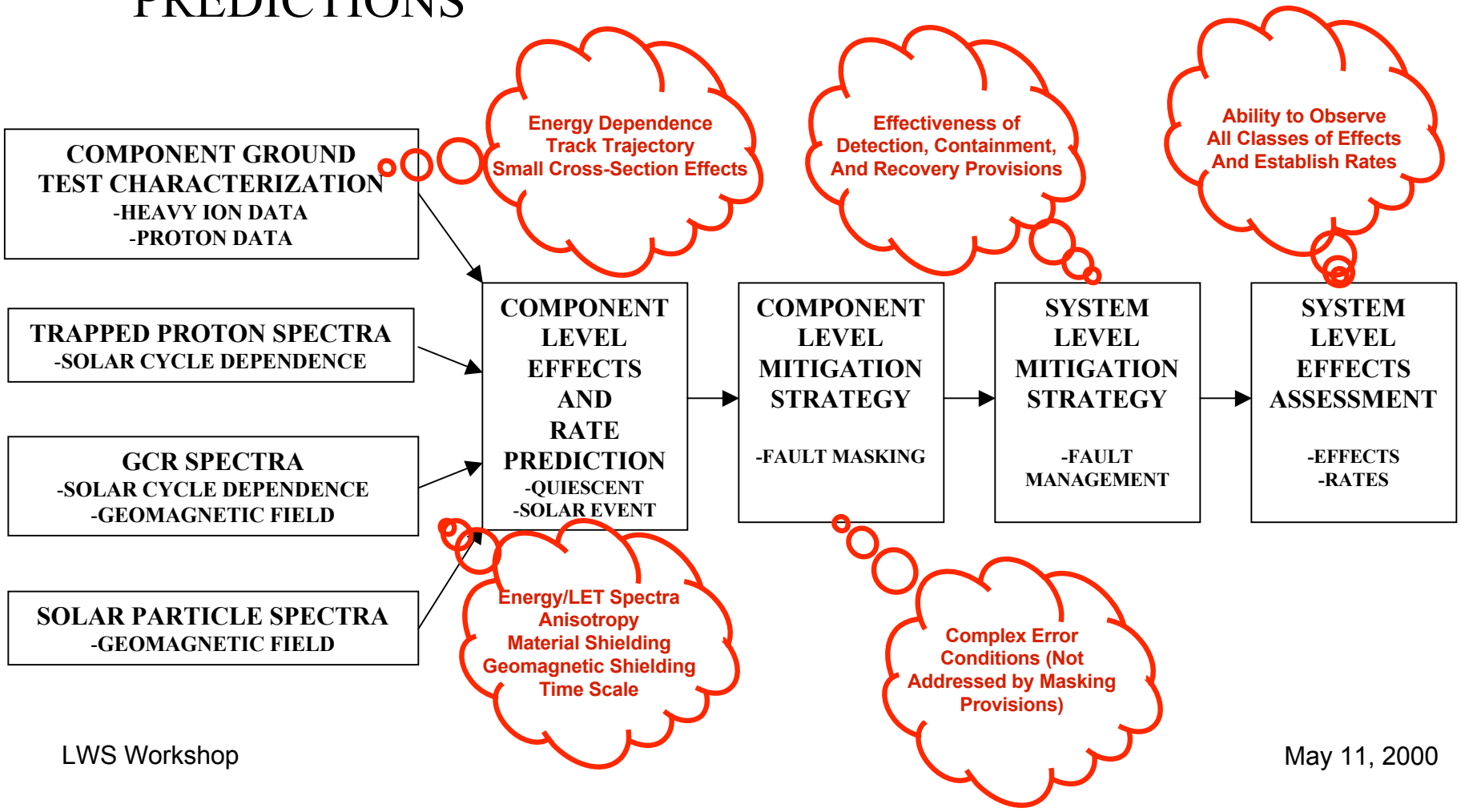
DEVELOPMENT METHODOLOGY

- VALIDATION AND VERIFICATION OF SYSTEM PERFORMANCE / AVAILABILITY



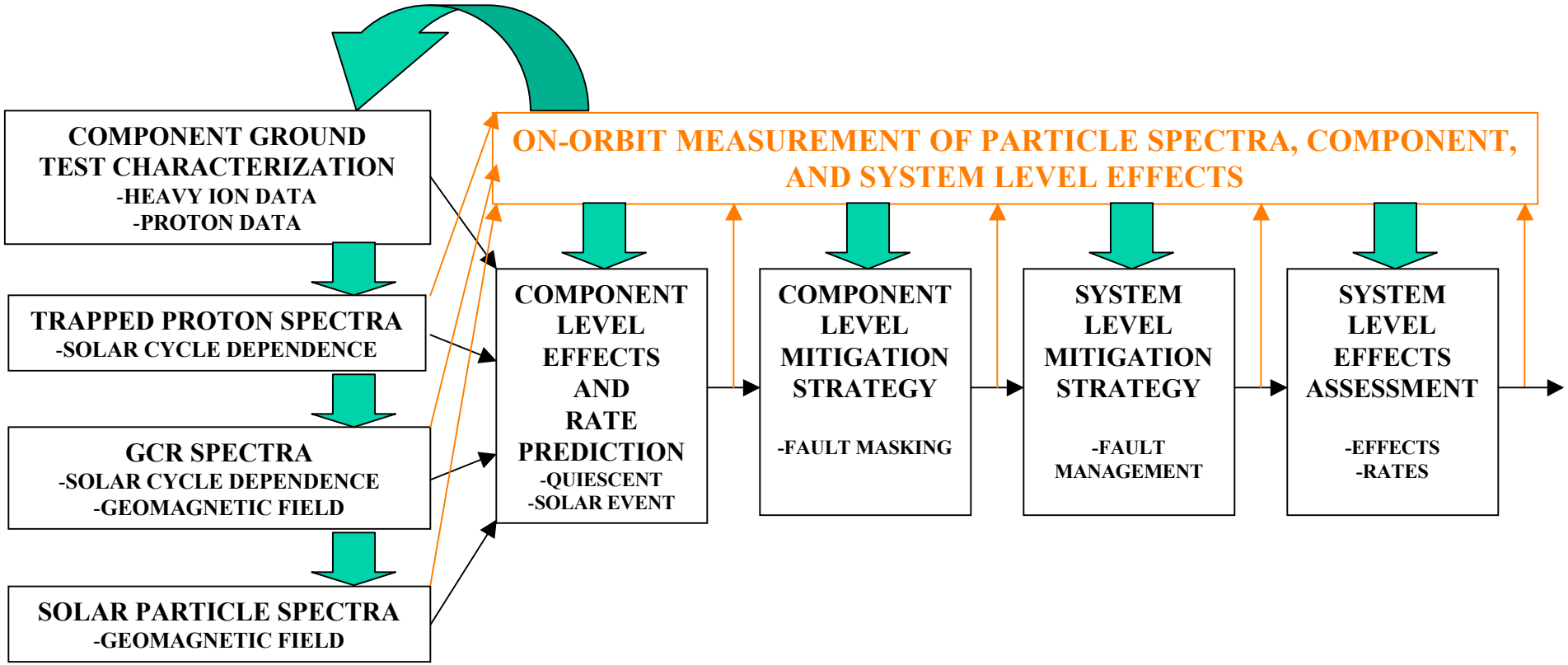
EFFECTS AND RATE PREDICTIONS

- UNCERTAINTIES IN EFFECTS AND RATE PREDICTIONS



IMPORTANCE OF TESTBEDS

- IMPORTANCE OF TESTBEDS IN VALIDATING DEVELOPMENT METHODOLOGY



IMPORTANCE OF TESTBEDS

- COMPATIBILITY WITH OTHER ASPECTS OF THE ENERGETIC CHARGED PARTICLE ENVIRONMENT.
  - Spacecraft Charging.
    - Validate Design Guidelines and Mitigation Provisions.
    - Correlation With Episodes of Severity in the Environment.
- RETIRE THE RISK ASSOCIATED WITH UTILIZATION OF NEW AND EMERGING TECHNOLOGIES.
  - Environmental Effects and Mitigation Strategies.
  - High Bandwidth Optical Inter-Satellite Links In a Constellation Which Uses Ion Propulsion.
    - Boundary Layer Effects in Proximity of Spacecraft.

SPACE WEATHER

- SPACE WEATHER SUPPORT OF COMMERCIAL CONSTELLATION OPERATIONS
  - Predictive Warning of Impending Severe Conditions.
    - Defer Critical Mission Operations Until Severe Conditions Subside.
      - Orbit Station-Keeping Maneuvers.
      - Upload of Operating Software.
    - Safe Satellites Against The Anticipated Threat.
    - Add Engineering and Analysis Staff to Mission Operations Team to Support Recovery of Affected Satellites.

SPACE WEATHER

- SPACE WEATHER SUPPORT OF COMMERCIAL CONSTELLATION OPERATIONS
  - Real-Time Reports and Descriptive Climatology.
    - Investigation of Space Segment Anomalies.
  - Quantitative Assessments Require the Ability to Transport the Near Earth Environment Down to the Orbit of Interest.
  - Coordinated Access to Integrated Space Weather Product.

- Energetic Charged Particle and Space Weather Related Inquiries.
  - I heard about increased solar activity today, what operational provisions should we employ?
  - F10.7 seems to correlate with this anomaly, what does that mean?
  - You predicted a specific rate, there seems to be a long term trend of decreasing single event upsets; what gives?
  - Day-to-day passes through the South Atlantic Anomaly show significant variance in the number of SEUs. Is this statistical variation due to the randomness of the SEU mechanisms, or is the environment severity really changing this much?
  - Should there be a difference in single event upset susceptibility for south-to-north versus north-to-south traverses through the SAA?
  - We have experienced several episodes of increased solar activity, CMEs, and geomagnetic disturbances and not observed significant effects in the system. Do we need to keep worrying about this?

CONCLUSIONS

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  - Unknowns and Uncertainties in the Environment, Its Effects, and the Effectiveness of Mitigation Strategies Results in Added Design Margins.
    - Increased Size, Weight, Power, and Cost of Satellite Systems.
    - Reduced Operational Capabilities.
  - Improved Understanding and Quantified Assessment of the Environment, Its Effects, and the Availability of Proven Mitigation and Fault Management Strategies and Techniques.
    - Enables Increased Operational Capability in Satellite Systems.
    - Space Environment Testbeds Provide the Increased Level of Knowledge.